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Iron fertilisation of the ocean through major volcanic eruptions. A case study of the Kasatochi eruption 2008

A. Lindenthal (1), B. Langmann (1), M. Hort (1), G. Hoshyaripour (1), J. Paetsch (2), and I. Lorkowski (2)

(1) University Hamburg, KlimaCampus, Institute of Geophysics, Hamburg, Germany , (2) University Hamburg, KlimaCampus, Institute of Oceanography, Hamburg, Germany

Until recently it was more or less common sense that once volcanic ash enters the ocean it simply deposits into the sediments without any further impact on ocean biochemistry. This view has been notably revised after the eruption of Kasatochi volcano in 2008. During the eruption significant amounts of ash were deposited into oceanic NE Pacific. The NE Pacific is known as a high-nutrient-low-chlorophyll (HNLC) region where algae growth is limited by the bio-available, i.e. soluble iron. These bio-available iron salts residing on the volcanic ash are most likely formed by gas-ash/aerosol interactions inside the volcanic plume. The physico-chemical mechanisms behind the processes contributing to bio-available iron production in volcanic plumes, however, are still poorly constrained. As the eruption occurred in early August, the atmospheric and oceanic conditions were favourable to generate a massive phytoplankton bloom as was observed by satellite instruments and in-situ measurements.

Here we investigate this event with the marine biogeochemical model ECOHAM, which is a regional scale three-dimensional ocean biogeochemistry model, coupled to the hydrodynamic model HAMSON. It has been successfully applied mainly over the NW European continental shelf area where iron limitation does not play a role. For applications of this model to the eruption of Kasatochi volcano, an iron cycle model has been implemented, which considers the influence of iron addition to the euphotic zone on diatoms, flagellates, and carbon dioxide concentrations. This model-approach assumes that all dissolved iron in the first meters of seawater is bio-available for phytoplankton uptake. It describes the limitation of phytoplankton growth rates by iron in addition to the limitation by the macro-nutrients nitrogen, phosphate and silicate as well as by light.

The surface ocean iron input associated with the eruption of Kasatochi volcano has been determined by an atmospheric-aerosol model to be on the order of 4.5-6x1011kg (ash volume of 0.23-0.3km3). This amount of volcanic ash is consistent with estimates from 1D eruption column models. ECOHAM model results show that volcanic ash can stimulate algae blooms in surface ocean waters in HNLC regions like the NE Pacific. Soluble iron released from volcanic ash acts as a key micro nutrient for phytoplankton growth, especially for diatoms. Model results have been verified with measurements of station Papa (50°N, 145°W). Here a deposition of bio-available iron of 968 micromol Fe/m2 into the surface ocean between Aug. 8-11 lead to an increase in the primary production of chlorophyll in the upper 10m of the ocean of 3.7mg Chl/m3. Following the ash deposition the CO_2 partial pressure at station Papa dropped by about 40microatm, which compares well with the 50microatm drop observed in our model calculations.